CITY COLLEGE OF SAN FRANCISCO

Gerald W. Bernstein, Principal Investigator

Undertaken in conjunction with: Chabot College, Pat's Garage, Perfect~Sky

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ELECTRIC VEHICLE SERVICE PERSONNEL TRAINING PROGRAM

SEPTEMBER 19, 2013

FINAL PUBLISHABLE REPORT

This report contains no proprietary data or information.

CITY COLLEGE OF SAN FRANCISCO – FINAL TECHNICAL REPORT

Project: Electric Vehicle Service Personnel Training Program

Primary Recipient: CITY COLLEGE OF SAN FRANCISCO

Principal Investigator: Gerald W. Bernstein, Director, Advanced Transportation

Technology and Energy program

Partners: CHABOT COLLEGE (Hayward, CA); PAT'S GARAGE (San Francisco, CA);

PERFECT~SKY (Los Angeles, CA)

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1. EXECUTIVE SUMMARY

As the share of hybrid, plug-in hybrid (PHEV), electric (EV) and fuel-cell (FCV) vehicles grows in the national automotive fleet, an entirely new set of diagnostic and technical skills needs to be obtained by the maintenance workforce. Electrically-powered vehicles require new diagnostic tools, technique and vocabulary when compared to existing internal combustion engine-powered models. While the manufacturers of these new vehicles train their own maintenance personnel, training for students, independent working technicians and fleet operators is less focused and organized. This DOE-funded effort provided training to these three target groups to help expand availability of skills and to provide more competition (and lower consumer cost) in the maintenance of these hybrid- and electric-powered vehicles.

Our approach was to start locally in the San Francisco Bay Area, one of the densest markets in the United States for these types of automobiles. We then expanded training to the Los Angeles area and then out-of-state to identify what types of curriculum was appropriate and what types of problems were encountered as training was disseminated.

The fact that this effort trained up to 800 individuals with sessions varying from 2-day workshops to full-semester courses is considered a successful outcome. Diverse programs were developed to match unique time availability and educational needs of each of the three target audiences. Several key findings and observations arising from this effort include:

- Recognition that hybrid and PHEV training demand is immediate; demand for EV training is starting to emerge; while demand for FCV training is still over the horizon
- Hybrid and PHEV training are an excellent starting point for all EV-related training as they introduce all the basic concepts (electric motors, battery management, controllers, vocabulary, testing techniques) that are needed for all EVs, and these skills are in-demand in today's market.
- Faculty training is widely available and can be relatively quickly achieved.
 Equipment availability (vehicles, specialized tools, diagnostic software and computers) is a bigger challenge for funding-constrained colleges.
- A computer-based emulation system that would replicate vehicle and diagnostic software in one package is a training aid that would have widespread benefit, but does not appear to exist. This need is further described at the end of Section 6.5.

The benefits of this project are unique to each of the three target audiences. Students have learned skills they will use for the remainder of their careers; independent technicians can now accept customers who they previously needed to turn away due to lack of familiarity with hybrid systems; and fleet maintenance personnel are able to lower costs by undertaking work in-house that they previously needed to outsource. The direct job impact is estimated at 0.75 FTE continuously over the $3\frac{1}{2}$ -year duration of the grant.

2. OBJECTIVES OF THE PROJECT

2.1 Project Goal and Approach

The overall objective of the proposed effort was to develop a series of interrelated curricula to train students (community college and secondary school), fleet personnel, and independent shop owners and technicians in the operation, safety, maintenance and repair of existing and emerging hybrid, PHEVs, EVs and FCVs. (We referred to the student, fleet and independent technician groups collectively as our "target audience.") Our team included auto program educators, a large municipal shop with a substantial hybrid and EV fleet, a PHEV conversion center and a firm that has provide independent hybrid and EV training for 10 years. The training prepared participants to understand existing models, and to prepare them for OEM vehicle-specific maintenance training in the future as new models are introduced.

We proposed and conduct our training in four phases over three and a half years. (Three years were originally proposed, but we added a 6-month no cost time extension.) The first phase ran for the entire project; it provided for our organization, management and reporting tasks. In our second phase, will developed draft curriculum (and tested existing recently-developed hybrid curriculum) with members of each target audiences allied-with the project team. In the third phase, we revised the curriculum for each group based on lessons-learned, and expanded it to the three target audiences in other San Francisco Bay Area locations; this provided insights into how to make the curriculum and equipment needs portable. In the fourth phase, we exported the curriculum for each target audience to other locations in California (where we have college auto program affiliations) and then to one other state to further understand how best to disseminate the developed information and curricula nationwide. Figure 1 at the top of the next page summarizes this approach.

City College of San Francisco (CCSF) is the lead organization; it participates in the statewide Advanced Transportation Technology and Energy (ATTE) initiative of the California Community College Chancellor's Office Economic and Workforce Development Division; as such, it has networked relations with other colleges throughout the state that provide transportation training.

2.2 Original Objectives versus Actual Measures

Our training goals and objectives are measured in two dimensions as suggested in Figure 1: target audience and geography. We achieved our instructional goals in each of these dimensions with only minor variation.

The three target audiences were students, fleet personnel and independent shop owners/technicians. Student courses were conducted at CCSF, Chabot College, College of Marin (SF Bay Area), Santa Rosa Jr. College (SF Bay Area), Solano College (SF Bay Area), Long Beach CC (LA Area), Rio Hondo CC (LA Area) and Mt. Hood CC (Portland, OR). The instruction provided at five locations was half-

or full-semester credit courses, while instruction at the other three locations (Solano, Rio Hondo and Mt. Hood) were in the form of multi-day workshops.

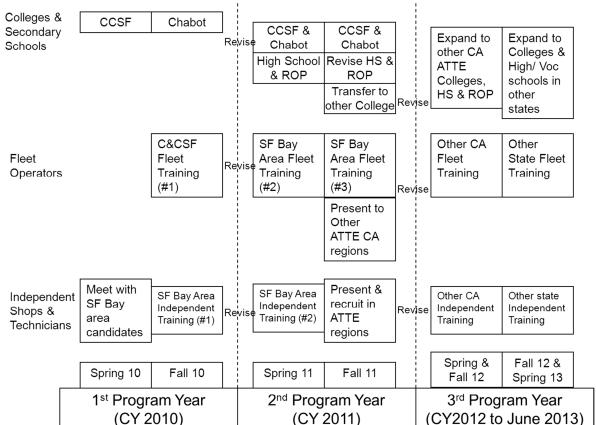


FIGURE 1. PROPOSED AND ACHIEVED APPROACH TO TRAINING

We found that high school and Regional Occupational Programs (RPOs) could not be modified to add hybrid course within the time line of the grant, so we provided supplemental instruction to existing courses by providing vehicles and instructors to existing auto maintenance classes.

Independent Shops and Technicians were the next easiest group to work with as they had strong professional and business incentives for hybrid and EV training. For them, this is business that they have had to turn away for lack of skill as hybrids have aged and owners have sought support outside the dealer network. Training for these professionals were conducted at CCSF, Rio Hondo Saddleback, and Santa Barbara Community Colleges in California; at the private school Wyotech in Sacramento, CA; and in neighboring states at Mt. Hood CC (Portland, OR) and Honolulu CC (Hawaii). (The workshop in Portland, OR, was attended by both students and working technicians.)

Finally, fleet operators were group that we expected would be straightforward to work with, but turn out to be the most difficult. Our primary focus was on

municipal fleets, though preliminary discussions were held with private fleets also.

We conducted a multi-day series of three workshops for the City and County of San Francisco (C&CSF) Municipal shops with 15 attendees. We solicited attendees for subsequent events at other locations, but each shop only had one or two individuals to attend and scheduling became a problem related to time-of-day, distance and availability of hosting facility. Other than the C&CSF training, we conducted only one other fleet training in California at Cerritos College. We solicited fleet participation in the neighboring state sessions, and some persons may have attended as individual technicians. But we did not have sufficient commitment to conduct dedicated training for fleet personnel in these locations.

However, with approximately 800 persons trained at all locations, we consider the overall program a successful training effort.

2.3 Research, Business or Education Improvement

The achievements of this grant are concentrated in Educational and Business improvements. There are no research impacts beyond suggestions for needed tools to facilitate further training at the end of section 6.5.

- 2.3.1 Education Impacts. Educational impacts were significant. We identify approximately 564 students, 224 independent technicians and 29 municipal fleet maintenance personnel who were provided hybrid and EV training as a result of this grant. (Details can be found in Section 5.) Five colleges were able to provide credit courses that would otherwise have been unavailable in this expanding field. Five other colleges were able to provide workshops for students and technicians to improve their job skills and employment prospects. Curriculum is now available to other colleges who want to expand their Hybrid and EV programs. One college at least we know of (Solano CC) has utilized the curriculum developed from this grant as part of their auto program.
- 2.3.2 Business Impacts. Business impacts are harder to measure as these occur over time. We have only anecdotal feedback that attendees were able to benefit from the education provided by increasing the number of vehicle types they are able to service.
- 2.3.3 Research Impacts. Not directly applicable. We did identify, however, one issue that needs future research attention in section 6.5.

A major impediment to hybrid, PHEV, EV and FCV training is the cost of the vehicle. This also has constraints the number of students that can work on vehicles at the same time (during a class) and difficulties for rural programs that might have lower student enrollment and therefore less means to justify acquisition of a vehicle. Diagnostic software has similar cost and availability constraints.

As a possible remedy to this situation, we identify that a Vehicle-Diagnostic emulator system would be highly desirable. Such a system would be entirely software based, including both the vehicle operating systems (in which an instructor could set error codes) and the diagnostic software. Vehicle system graphics and displays replicating the look and functionality of diagnostic software would make this a complete training package. This would allow all students in a class to work on common or individual trouble-shooting problems simultaneously, and eliminate the "logjam" created by a shortage of vehicles and/or software. Such a system could be used in rural or urban classes, significantly reducing any disadvantage that rural and small community auto programs might encounter due to equipment constraints.

2.4 Job Creation (If Applicable)

The immediate Job Creation impact of this grant varied by quarter depending on the teaching load, meetings (e.g. "Annual Merit Review and Peer Evaluation" presentations) and other administrative activities. On average, our records indicate the grant created 0.75 Full Time Equivalent jobs each year. This is divided into faculty, administrative time and support (secretarial, accounting) time. The amount, of each varies by quarter.

3. SCIENTIFIC AND TECHNICAL RESULTS

The primary goal for this project was education. As such, scientific and technical results were not a significant part of our workplan.

We did, however, support and participate in an environmental scan of "Hybrid Vehicle Maintenance and Repair Occupations" in 2010 that addressed the employment and training needs of auto maintenance and repair facilities in three SF Bay Area counties (Alameda, Contra Costa and Solano). The survey received replies from 150 employers; 10% of the automotive employers in the three counties.

It was found that 68% of local employers had the "greatest" interest or "some" interest in weekend or weeknight training programs for their current service technicians; 67% were similarly interested in a "customized" program to address their upskilling needs. Lower interest was expressed by these employers in a hybrid-certificate program.

4. USE OF RESOURCES

This section includes a description of the resources and equipment employed during the course of the project.

4.1 Use of Financial Resources

A tabular summary of the financial performance is provided below. As indicated in the *Final Actual Cumulative Budget* table, there are some differences between our final budget and our final revision of March 2012 (15 months from project completion), though most of these are minor. The ones that are most significant, are categories "d. Equipment" and "e. Supplies."

FINAL ACTUAL CUMULATIVE BUDGET (FEDERAL SHARE ONLY)

		March 2012	Final Actual Cumulative
Category	<u>Original</u>	Revise	Budget
a. Personnel	\$52,450	\$64,450	\$65,970
b. Fringe Benefits	\$15,735	\$21,734	\$21,005
c. Travel	\$15,770	\$6,928	\$5,148
d. Equipment	\$20,000	\$14,410	\$0
e. Supplies	\$12,110	\$1,000	\$14,994
f. Contractual	\$0	\$0	\$0
g. Training Support Costs	\$0	\$0	\$0
h. Other	\$355,634	<u>\$363,177</u>	<u>\$364,582</u>
i. Total Direct Charges (sum of a- h)	\$471,699	\$471,699	\$471,699
j. Indirect Charges	\$28,302	<u>\$28,302</u>	\$28,302
k TOTALS (sum of I and j)	\$500,001	\$500,001	\$500,001

We have not purchased any items of value over \$5,000. Our (City College of San Francisco) accounting system treats all computer and software purchases as "equipment," so there was confusion in terms when we were undertaking our budgeting. The full list of purchased goods includes the following:

- 2 Durabook ® computers for shop use (total expense \$2,093.94)
- 4 Techstream ® software and cable subscriptions (total \$7,017.52)
- 13 DEKA ® sealed batteries for a class EV (total \$2,617.55)
- 6 Pairs of electrical linesmen gloves (total \$394.94).

Our *Final Actual Cumulative Budget* tally includes these items (and smaller items such as photocopier expenses and the like) as "supplies."

The Principal Investigator is employed as a consultant at the college; his expenses are identified as "Other." This category also includes expenses to subrecipients and other training partners.

4.2 Subrecipients and Other Participants

Subrecipients included Chabot College (Hayward, CA), Pat's Garage and Perfect~Sky. The Chabot College automotive program developed college and High School / Regional Occupational Program (ROP-- also called Vocational Technical High School) programs. They provided nine credit courses during the course of the grant.

Mr. Pat Cadam (co-Owner of Pat's Garage) has been a licensed automotive service technician for 25 years; in the past 5 years, he has been the Northern California partner facility for A123/ Hymotion's Plug-In Prius conversion efforts. As such, he and his technicians have been involved in the conversion and support of dozens of Plug-In Prius conversions now in fleet use with the City & County of San Francisco, Google and Pacific Gas & Electric, in addition to those in individual ownership. His shop now hosts a ChargePoint EV charging station. Mr. Cadam and his partner hosted training for mechanics at their shop and provided training on several occasions to working technicians, and college and high school students.

Mr. Jack Rosebro is the founder of Perfect Sky, a company that has been training automotive technicians, educators, and engineers on the theory, analysis, operation, diagnosis, and/or repair of hybrid, plug-in hybrid, and electric vehicles for 15 years. He is now an Instructor and Program Developer with SAE International. Mr. Rosebro taught a number of the workshops to independent technicians and college students in both Northern and Southern California.

Other training partners (in addition to CCSF and our subrecipient partners) conducted or hosted training in California and neighboring states. These included Santa Rosa Jr. College, College of Marin, Solano College, Santa Barbara Community College (CC), Saddleback College, Rio Hondo College, Cerritos College, Mt. Hood CC (Portland, OR), Honolulu CC (Hawaii) and Wyotech (a division of private Corinthian Colleges). San Francisco Municipal shops hosted training for fleet personnel. In some cases the colleges were funded to provide the instruction; in other cases the trainer was funded and the colleges provided facilities and support.

5. LIST OF DELIVERABLES

As previously indicated, approximately 800 individuals (students and technicians) received training through this grant. Instruction was provided through 42 training events, courses and/or workshops. A summary of these events and enrollment is provided below. In addition, purchased items ("Supplies" as enumerated in section 4. *Use of Resources* above) were provided to colleges in support of their programs.

UNDERGRADUATE COURSES OFFERED			
Introduction to Hybrid	Classes Offered	3	
Auto Maintenance & Repair; CCSF; Auto 56	Student Enrollment	75	
Alternative Fuel &	Classes Offered	3	
Hybrid Vehicles; CCSF; Auto 57	Student Enrollment	65	
Hvbrid & EVs LBCC	Classes Offered	1	
Hybrid & EVs LBCC	Student Enrollment	24	
Florida O. H. I. d. I. COM	Classes Offered	1	
Electric & Hybrid COM	Student Enrollment	22	
Hybrid & EVa SDIC	Classes Offered	1	
Hybrid & EVs SRJC	Student Enrollment	21	
	NUMBER OF UNDERGRADUATE COURSES	9	
	NUMBER OF STUDENTS	207	

TECHNICAL COURSES OFFERED		
Hybrid Vehicle Operation & Servicing; Chabot;	Courses Offered	5
ATEC 90	Enrollment	125
Hybrid Diagnostic & Alternative Fuel	Courses Offered	4
Technology; Chabot; ATEC 91	Enrollment	105
	NUMBER OF TECHNICAL COURSES	9
	NUMBER OF STUDENTS	230

SHORT COURSES OFFERED (< 1 WEEK)			
Hybrid Vehicle Safety and Maintenance (SF	Courses Offered	3	
Municipal)	Attendance	15	
Hybrid/EV Diagnostics,	Courses Offered	2	
Safety and Repair (SF Independents)	Attendance	19	
Hybrid Diagnostics and Repair (Bay Area	Courses Offered	2	
Independents)	Attendance	35	
Hybrid/EV Diagnostics, Safety and Repair;	Courses Offered	1	
Portland, OR	Attendance	18	
Introduction to Hybrid Maintenance and Repair	Courses Offered	4	
(Independents), Rio Hondo; Saddleback; SBB	Attendance	60	
Introduction to Hybrid	Courses Offered	1	
Maintenance and Repair (Faculty); Honolulu CC	Attendance	12	
Introduction to Hybrid	Courses Offered	3	
Maintenance and Repair (Independents), Wyotech	Attendance	80	
Hybrid Vehicle Safety and	Courses Offered	1	
Maintenance (LA-area Municipal); Cerritos	Attendance	14	
	NUMBER OF SHORT COURSES	17	
	NUMBER OF ATTENDEES	253	

OUTREACH EVENTS		
Solano college support,	Number of Events	2
spring 2012	Attendance	30
Mission Valley ROP, San Leandro HS, James Logan	Number of Events	4
HS, Westmore HS; educational events	Attendance	85
CCSF, Supplemental instruction to existing	Number of Events	1
hybrid program, Summer 2012.	Attendance	12
	NUMBER OF TRAINING EVENTS	7
	NUMBER OF ATTENDEES	127

TOTAL NUMBER OF TRAINING EVENTS & COURSES	42
NUMBER OF ATTENDEES	817

The supplies purchased for participating colleges were described above in Section 4, *Use of Resources*. They included four Techstream ® Prius diagnostic software packages and connection cables, two Durabook laptop computers for shop use, 13 lead-acid batteries to refurbish an EV used in a class, and 6 pairs of electrical lineman's gloves. No single item exceeded \$5,000 in price.

6. RESULTS AND CONCLUSIONS

According to our Statement of Project Objectives, the proposed effort was to develop a series of inter-related curricula to train students (community college and secondary school), fleet personnel, and independent shop owners and technicians in the operation, safety, maintenance and repair of existing and emerging hybrid, PHEVs, EVs and FCVs. (We refer to the student, fleet and independent technician groups collectively as our "target audience.") The training was intended to prepare participants to understand existing models, and to participate in OEM vehicle-specific maintenance training in the future as new models are introduced.

We proposed to conduct our training in four phases over three years. The first phase was proposed to be conducted over the entire project; it provided for our organization, management and reporting tasks. In our second phase, we proposed to develop draft curriculum (and test existing recently-developed hybrid curriculum) with members of each target audiences allied-with the project team. In the third phase, we proposed to revise the curriculum for each group based on lessons-learned, and expand it to the three target audiences in other San Francisco Bay Area locations. In the fourth phase, we proposed to export the curriculum for each target audience to another location in California and to one or more other states to further understand how best to disseminate the developed information and curricula. The proposed phases and specific tasks are identified in the following, along with a brief description of how we accomplished each.

Phase 1. Project Organization and Management

In summary, this Phase went slower than planned, but all Tasks were completed as envisioned.

<u>Task 1. Project Management and Planning</u>. Meetings were held as scheduled with the CCSF Associate Vice Chancellor with oversight responsibility for this project. Project progress was reported; any issues were discussed and resolutions developed.

<u>Task 2. Technical Review Committee Meetings</u>. These were held periodically during the grant, more in the early years than in the later years when the workplan was mature and in implementation.

<u>Task 3. Complete MOUs and Contracts</u> These were mostly completed during the first year, though some of the final ones were not fully executed until the final months of the grant.

Task 4. Provide Required Reports to DOE. Through the grant we have provided quarterly DOE Progress Reports and ARRA reports on schedule. We presented our progress at two Annual Merit Review Meetings (2011 and 2012).

Phase 2 (Year 1): Draft Curriculum and Initial Training

In summary training for students and Independent technicians were easier to schedule and complete than High School and Municipal Fleet trainings due to time restrictions on the latter two groups.

Task 5.0. Develop College and Secondary School Hybrid Courses. Both CCSF and Chabot College piloted hybrid and EV classes during 2010. A shorter version was discussed with high schools and Regional Occupational Programs (ROPS), but it was found that a full class could not be accommodated due to existing course requirements. Modules would be acceptable, however, as supplements to existing courses. These were developed by two of our subrecipients.

<u>Task 6.0. Develop Instruction Program for Fleet Operators.</u> We reviewed the training needs of San Francisco's Municipal Shop with its management and union. An initial training module focusing on safety was developed for faculty and our sub-recipients. The program was provided to Shop personnel during the summer of 2010. Following this program, we incorporated revisions based on feedback.

<u>Task 7.0.</u> <u>Develop Instruction Program for Independent Shops and Technicians.</u> Using existing curriculum, our subrecipients provided our first series of trainings to independent technicians during 2010. These proved to be successful and validated the emphasis on safety and enhancing knowledge of battery construction, operation and diagnostic. More time is clearly needed for learning diagnostic software (such as Techstream for the Prius).

Phase 3 (Year 2): Refine Curriculum and Expand to Other Locations Within the San Francisco Bay Region

In summary, training expansion was relatively easy for High School students, Independent Technicians and Fleet Operators as these were of shorter duration so that vehicles and instructors could be moved as needed. College-based training was difficult at locations that did not have a hybrid auto or previously trained faculty.

Task 8. Expand College Programs and Initiate Secondary School Programs. During the second program year, we supported Hybrid and EV Maintenance and Repair courses at two SF Bay Area Colleges: College of Marin (COM) and Santa Rosa Jr. College. We also provided COM with a laptop computer and Techstream subscription. Secondary school hybrid/ EV workshops were provided as part of existing courses at San Leandro and James Logan high schools, and at the Mission Valley ROP (all in the SF Bay Area).

Task 9.Refine and Expand Fleet Operator Training. We conducted interviews and discussions with other area fleets, but the smaller size of these fleets and maintenance facilities led to scheduling difficulties resulting in no classes this year despite several tentatively scheduled. We also reviewed with the San Francisco shops what added training would be useful, but the worsening municipal budget situation statewide (which was part of the problem with the

other area shops) undermined efforts to schedule a follow-on course to our first year training.

Task 10.Refine and Expand Independent Shop and Technician Training. Faculty and subrecipients cooperated to provide another training event for independent technicians during 2011. Also, and ahead of schedule, we conducted a training for independent technicians in the Portland, OR area at Mt. Hood CC. We had been negotiating with them for Phase 4/ Task 11 (student) participation, but they identified an immediate need for Phase 4/Task 13 (technician) assistance.

Phase 4 (Year 3 extended): Expand Training to Other Parts of California and Neighboring States

In summary, as above, training expansion was relatively easier for High School students, Independent Technicians and Fleet Operators as these were of shorter duration so that vehicles and instructors could be moved as needed. College-based training was difficult at locations that did not have a hybrid auto or previously trained faculty.

Task 11. Expand College Programs and Secondary School Programs. During the extended (18 month) final year of our program, we provided student training at locations in other parts of California and neighboring states. Student training was provided as a full semester course at Long Beach CC and with mixed student/technician workshops at Rio Hondo, Saddleback and Santa Barbara community colleges. Workshops were also provided to students at private Wyotech College. Secondary school programs were conducted, but these remained in the SF Bay Area; hybrid/EV workshops were provided to several classes at Westmore High School.

<u>Task 12.Refine and Expand Fleet Operator Training.</u> Fleet operator training was provided at Cerritos College to four Los Angeles-area municipal fleets. Fleet operators were notified of the Mt. Hood training session (see Task 10, above), but none attended.

Task 13.Refine and Expand Independent Shop and Technician Training. As described in Task 11, we provided mixed student / technician workshops at a number of locations in the Los Angeles and Santa Barbara areas. These were in addition to the Portland, OR, training provided during the previous year (Task 10). To further test the portability of Hybrid, PHEV, EV and FCV technician training, we also conducted an out-of-state training at Honolulu Community College as our contacts at Mt. Hood CC in Portland were unable to confirm a second training opportunity. The Honolulu training was provided to both technicians and faculty, so that the benefits did flow indirectly to students.

Overall Observations and Conclusions

We have obtained a few insights into developing Hybrid training programs from this effort. Key points are as follows.

- Recognition that hybrid and PHEV training demand is immediate; demand for EV training is starting to emerge; demand for FCV training is still over the horizon
- Hybrid and PHEV training are an excellent starting point for all EV-related training as they introduce all the basic concepts (electric motors, battery management, controllers, vocabulary, testing techniques) that are needed for all EVs, and these skills are in-demand by technicians in today's market.
- Faculty training is widely available and can be relatively quickly achieved with the use of experienced instructors and workshops which are publically available at varying costs. Equipment availability (vehicles, specialized tools, diagnostic software and computers) is a bigger challenge for funding-constrained colleges. Used vehicles or vehicles reclaimed by insurance companies have helped our college programs, but these generally represent a generation (or half-generation) older technology. This is less of a problem for working technicians, however, as they don't typically see models in their (independent shops) until they are out-of-warranty—typically 4 or 5 years after new model introduction.
- Secondary school curriculums are tightly defined and time constrained.
 The most acceptable way to introduce Hybrid and EV maintenance issues is to add a module to existing auto maintenance classes.
- The cost of class vehicles and diagnostic software cause a bottleneck in student learning opportunities. A student in a class of 25 might have only a few hours per semester to actually work with the software and vehicle due to demand for access by other students and classes. A computerbased emulation system that would replicate vehicle and diagnostic software in one package is a training aid that would have widespread benefit as students could spend enough time to understand the full procedure for resolving instructor-introduced problems. Such a training aid does not appear to exist.

The reasons for the lack of such a system are many. First, auto manufacturers provide their own proprietary diagnostic software to support their own vehicles. Within their networks of trained technicians, everyone learning to use the software is provided a vehicle to work on. If an independent party chose to develop a software package, there would likely be issues around property rights related to the "look and feel" of an aftermarket system. Such an independent developer would also need to choose which manufacturer's system to replicate as there are many on the market. Finally, even if such a system were developed and marketed, it would need to be updated regularly (at least annually to accommodate new models). Thus all-in-all, a significant time and development investment would be required to serve a market need, but one of unknown size.

7. REFERENCES

Centers of Excellence, California Community Colleges Chancellor's Office, <u>Hybrid Vehicles</u>, <u>Maintenance and Repair Occupations</u>, August 2010; downloaded from: http://www.coeccc.net/environmental_scans/hybrid_bay_scan_10.pdf

Erjavec, Jack & Jeff Arias, <u>Hybrid, Electric and Fuel Cell Vehicles</u>; Delmar, Cengage Learning; Clifton Park, NY. 2013.

Halderman, James D and Tony Martin., <u>Hybrid and Alternative Fuel Vehicles</u>; Pearson Education; 1st edition (2009), (3rd (2013) edition now available.)

Rosebro, Jack (Perfect Sky), <u>Basic Hybrid Powertrains</u>; privately published and distributed.

<u>Instructor handouts</u>. These are essential as the technology of these vehicles is rapidly evolving. <u>Popular Mechanics</u>, <u>Car and Driver</u>, <u>Road and Track</u>, and <u>Automotive Engineering</u> typically run features on new hybrid and electric car developments.

<u>Websites</u>. Some of these provide text, others provide cut-away and operating views. Specific sites changed frequently from class to class depending on date and instructor.

8. ANNEXES

AUTO 56 Introduction to Hybrid Auto Maintenance and Repair City College of San Francisco, 17 Week Course

I. MAJOR LEARNING OUTCOMES

Upon completion of this course a student will be able to:

- A. Demonstrate knowledge of Introductory Principles, Motor and Generator Basics, and Battery Basics (Major Topics A, B and C).
- B. Identify on a vehicle the various Hybrid System components (Major Topic D).
- C. Describe the function of Hybrid System components (Major Topic D).
- D. Demonstrate safety procedures and describe their critical importance (Major Topic E).
- E. Perform routine maintenance per manufacturer specifications (Major Topic F or G depending on available vehicle).
- F. Diagnose and solve mechanical and electrical problems (Major Topic F or G depending on available vehicle).
- G. Demonstrate knowledge of and appropriate use of test equipment (Major Topic F or G depending on available vehicle).

II. CONTENT

- A. Introductory Principles.
 - 1. Hybrid and Electric Vehicle Vocabulary
 - 2. Hybrid and Electric Vehicles in Production
 - 3. Types of Hybrid Systems
 - a. Series.
 - b. Parallel.
 - c. Series.
 - d. Series/Parallel.
 - e. Mild and Assist Hybrids.
 - f. Plug-in Hybrids
 - 4. Electrical Theory Basics
 - a. Electrical Basics.
 - b. Safety Implications.

B. Motor and Generator Basics.

- 1. Basic Motor Operations
 - a. Series.
 - b. Parallel.
- 2. Generators
- 3. Motor Generators
- 4. Controllers

C. Battery Basics.

- 1. Lead-Acid (Pb-A)
- 2. AGM Battery (12 volt system)

- 3. High-Voltage (HV) System Batteries
 - a. NiMH
 - b. Li-Ion and other new battery technologies
 - c. Importance of HV State-of-charge.
- D. Hybrid System Components and Operation.
 - 1. System Components
 - a. ICE and MG
 - b. Battery Pack
 - c. Rectifiers, Inverters, Converters
 - d. Cables, Switches
 - 2. Battery Charging
 - 3. Regenerative Braking
 - 4. Fuel Tank and Systems
 - 5. Driving
- E. Safety.
 - 1. Personal Safety
 - 2. Gloves
 - 3. Tools and Equipment
 - a. Mega-ohm meter.
 - b. Scanners (eg, Toyota TIS).
 - c. Using appropriate fluids.
 - 4. Safety Procedures (Shop)
 - a. Depowering HV System
 - b. Importance of ensuring auto in shutdown mode.
 - c. Repowering HV System
 - 5. Safety Procedures (Test Driving)

(Note: Emphasis on F or G will depend on specific vehicle(s) available)

- F. Honda and/or GM (Mild Hybrid) Systems.
 - 1. Routine Maintenance (unique to this type of hybrid system)
 - a. System-specific Fluids.
 - b. Other System-specific requirements (e.g., Brakes).
 - 2. Diagnostics (for Hybrid-system related problems)
 - a. Types and use of test equipment
 - b. Reading data codes
 - c. Assuring proper use of fluids
- G. Toyota and/or Nissan (Full Hybrid) Systems.
 - 1. Routine Maintenance (unique to this type of hybrid system)
 - a. System-specific Fluids.
 - b. Other System-specific requirements (e.g., Brakes).
 - 2. Diagnostics (for Hybrid-system related problems)
 - a. Types and use of test equipment

- b. Reading data codes
- c. Assuring proper use of fluids

III. INSTRUCTIONAL METHODOLOGY

A. Assignments

1. In-class Assignments

- a. Participation in class discussion of Principals (Content A, B and C), Operational Basics (D), Safety Procedures (E), and the Maintenance and Diagnostic procedures appropriate to sample vehicle (F and/or G).
- b. Demonstrate knowledge of principles by using appropriate tools and procedures when working on sample vehicle ((E) Safety procedures should be followed and (F and/or G) knowledge of Routine Maintenance and Diagnostic procedures should be demonstrated). Knowledge will be demonstrated by participation in a group conducting routine diagnostics and maintenance on a college vehicle (or vehicles), and by responding to instructor questions to individual group members.

2. Out-of-class Assignments

- a. Completion of paper analyzing one of the current (Toyota, Honda, Nissan or GM) Hybrid auto systems. Such a paper would be expected to demonstrate knowledge of the operation of the particular system, its strengths, its weaknesses and the complexity it adds to a non-hybrid vehicle (both mechanical and electrical). A summary of the findings would be presented in class to enable other students to improve their understanding of the competing systems and their functionality.
- b. Evaluations of on-line resources. Each student will be expected to critique either a manufacturer or independent web-site providing information on hybrid system operations. This will assist students in understanding the types of information that they will be able to obtain from on-line resources.
- c. Textbook and hand-out reading assignments.

B. Evaluation

1. Written Exams

- a. Pass two written exams on the subjects of the course. The first exam will emphasize Principles, Basics, Components and Operations (Content A, B, C and D). The second exam will emphasize Safety, Maintenance and Diagnostic Procedures (E and F and/or G). Student demonstration of hybrid auto maintenance and diagnostic procedures
- b. Demonstrate ability to diagnose a sample problem arranged by instructor. For example, "Demonstrate (or describe, as appropriate) the procedure for testing insulating gloves before each use. ______ "

C. Textbooks and other Instructional Materials

1. Textbooks

- a. Erjavec, Jack & Jeff Arias "Hybrid, Electric & Fuel Cell Vehicles"
- b. Rosebro, Jack for Perfect Sky, "Basic Hybrid Powertrains"
- c. And/or equivalent to the above

- 2. Instructor handouts. These will be essential as the technology of these vehicles is rapidly evolving. <u>Popular Mechanics</u>, <u>Car and Driver</u>, <u>Road and Track</u>, and <u>Automotive Engineering</u> typically run features on new hybrid and electric car developments.
- 3. Websites. Some of these provide text, others provide cut-away and operating views. Examples omitted from this report as they changed frequently from class to class.

ATEC90 Hybrid Diagnosis and Alternate Fuels Technology Chabot College, 8 Week Course

Lecture 1

- 1. Orientation
 - a. Welcome
 - b. Introductions
 - c. Emergency procedures
 - d. Syllabus overview
 - e. Study Skills and personal motivation
 - f. Demo College Automotive Website
 - g. Demo Blackboard or other student management system website
 - h. Facilities Tour-General, tool check out process (If some students are new to school)
- 2. Chapter 1: Carbon-Based Fuels and the Environment

Lab 1

- 1. Look up safety precautions / procedures for the available vehicles
 - a. HV disconnect device
 - b. Conformation of HV system disconnect
 - c. Handling of HV system components
 - d. HV battery
 - e. Converter
 - f. Controller
 - g. Motor
- 2. Look up component locations for
 - a. 12v battery
 - b. HV battery
 - c. Disconnect fuse
 - d. Converter
 - e. Controller
 - f. Motor
- 3. Identify these components on the vehicle(s)
- 4. Demo Cat III DMM
- 5. Demo hybrid battery chargers

Lecture 2

- 1. Chapter 2: Introduction to Hybrid Vehicles
- 2. Chapter 12: Safety and Service procedures

^{*}Homework Assignment: Read Chapter 2, complete chapter quiz p.28-29 due next lecture day (Ref: <u>Hybrid and Alternative Fuel Vehicles</u>, Halderman; 1st edition at that time, published by Pearson Education)

^{*}Homework Assignment: Read Chapter 12, complete chapter quiz p.250 due next lecture day

- *Homework Assignment: Read Chapter 7, complete chapter quiz p.130-131 due next lecture day
- *Homework Assignment: Read Chapter 18, complete chapter quiz p.356 due next lecture day

Lab 2

- 1. Demo safety equipment
 - a. Pole
 - b. Gloves
 - c. Glove test
- 2. Look up applicable directions and perform HV system disconnects
- 3. Look up applicable directions and perform conformation of HV system disconnect

Lecture 3

- 1. Chapter 7: Hybrid Batteries and Battery Service
- 2. Chapter 18 Fuel Cells and Advanced Technologies
- *Homework Assignment: Read Chapter 8, complete chapter quiz p.154 due next lecture day

Lab 3

- 1. Demo applicable scan tool device(s)
- 2. Perform data acquisition for
 - a. Batteries
 - b. Motor Control
- 3. Look up applicable directions and perform 12v charging system tests

Lecture 4

- 1. Chapter 8: Electric Motors, generators, and Controls
- *Homework Assignment: Read Chapter 3, complete chapter quiz p.64 due next lecture day

Lab 4

- 1. Demo proper testing / servicing of the cooling systems for
 - a. Battery
 - b. Converter / Inverters
- 2. Look up applicable directions and perform applicable HV cooling systems tests / services

Lecture 5

1. Chapter 3: IC Engine

^{*}Homework Assignment: Read Chapter 8, Power Steering p.151-153 due next lecture day

*Homework Assignment: Read Chapter 11, complete chapter quiz p.235 due next lecture day

Lab 5

- 1. Access IC engine data with applicable scan tool(s)
- 2. Look up applicable information and identify appropriate fluid types for IC Engine
- 3. Look up applicable directions and perform inspection of IC Engine fluid levels

Lecture 6

- 1. Chapter 8: Power Steering
- 2. Chapter 11: Hybrid Vehicle Heating and Air Conditioning
- *Homework Assignment: Read Chapter 9, complete chapter quiz p.166-167 due next lecture day
- *Homework Assignment: Read Chapter 10, complete chapter quiz p.205 due next lecture day

Lab 6

- 1. Access Power Steering system data with applicable scan tool(s)
- 2. Access HVAC system data with applicable scan tool(s)
- 3. Perform component ID for Power Steering system
- 4. Perform component ID for HVAC system

Lecture 7

- 1. Chapter 9: Regenerative Braking Systems
- 2. Chapter 10: Hybrid Vehicle Transmissions and Transaxles

Lab 7

- 1. Access Brake system data with applicable scan tool(s)
- 2. Access Transmission / Transaxle data with applicable scan tool(s)
- 3. Perform component ID for Brake system
- 4. Perform component ID for Transmission / Transaxle system
- 5. Look up applicable directions and perform brake inspection

Lecture 8

1. Final Exam

Lab 8

- 1. Practical Examination
 - a. Demonstrate the proper methods to perform a glove check
 - b. Demonstrate the proper methods to perform a HV system disconnect
 - c. Demonstrate the proper methods to confirm the HV system is disconnected
 - d. Access battery data with applicable scan tool(s)
 - e. Access engine data with applicable scan tool(s)
 - f. Hybrid vehicle component identification

ATEC 91 Hybrid Diagnosis and Alternate Fuels Technology Chabot College, 8 Week Course

Lecture 1

- 1. Orientation
- 2. Q & A Review of Hybrid vehicle systems and safety (Chapter 2 & 12)
- 3. Capacitors
- 4. High Voltage Batteries
 - a. Types
 - b. Attributes of the different types
 - c. Plug-in technology
 - i. Operation
 - ii. Expanded electric only range
 - iii. Reduction in petroleum based fuel use
 - d. Removal
 - e. Testing

Lab 1

- 1. High Voltage battery removal
- 2. Dissemble and inspect

Lecture 2

1. Inverters and Converters

Lab 2

- 1. Inverter / Converter R&R
- 2. Cooling system bleeding (If Applicable)

Lecture 3

- 1. Electric motor operation
 - a. Motor / generator
 - b. Direction of operation
- 2. Meters
 - a. Operation / Application
 - b. Testing

Lab 3

- 1. Transmission disassembly
- 2. Motor winding tests
- 3. Observe motor operation via data stream on dyno
 - a. Direction (motor / generator)

Lecture 4

- 1. Electric Vehicles
 - a. Current models
 - b. Charging

- i. IC motor
- ii. Regenerative Braking
- iii. Slow (110v)
- iv. Fast (220/440)
- v. Battery Exchange
- c. Benefits
 - i. Emissions
 - ii. Noise pollution
 - iii. Cost to operate
 - iv. Personal satisfaction / beliefs
- d. Negatives
 - i. Raw material costs
 - ii. Hazmat / recycle
 - iii. Effects of climate (Performance in cold environments)
 - iv. Operating range
 - v. Return on investment (Purchase cost vs fuel cost savings)

Lab 4

- 1. Transmission disassembly
- 2. Motor winding tests
- 3. Observe motor operation via data stream on dyno
 - a. Direction (motor / generator)

Lecture 5

- 1. Clean Diesel (Chapter 6)
 - a. Benefits for hybrid applications
 - b. Attributes
 - c. Engines
 - d. Emissions devices

Lab 5

- 1. Diesel vehicle
- 2. Component ID
- 3. Access available scan tool data

Lecture 6

- 1. Alternate Fuels (Chapter 5)
 - a. Benefits for hybrid applications
 - i. E85
 - 1. Attributes
 - 2. Fuel requirements (Component changes to allow E85 use)
 - ii. CNG
 - 1. Attributes
 - 2. Fuel requirements (Component changes to allow CNG use)

- iii. LPG
 - 1. Attributes
 - 2. Fuel requirements (Component changes to allow LPG use)

Lab 6

- 1. Alt Fuel Vehicles
- 2. Component ID
- 3. Access available scan tool data

Lecture 7

- 1. Hydrogen (Chapter 18)
 - a. Hybrid / electric applications
 - i. IC Motor
 - ii. Fuel Cell
 - 1. Liquid applications
 - 2. Gas applications
 - b. Benefits
 - i. Available resource
 - ii. Emissions
 - c. Negatives
 - i. Availability to customer
 - ii. Safety Concerns

Lab 7

- 1. Shop Practical
 - a. Component ID
 - b. Meter usage
 - c. Safety procedures
 - d. Data access

Lecture 8

- Final Exam
 - a. 50 question
 - i. Multiple choice

Lab 8

- 2. Shop Practical
 - a. Component ID
 - b. Meter usage
 - c. Safety procedures
 - d. Data access
 - e. Information resources usage

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